LA-UR-02-4042

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Submitted to: American Nuclear Society
2002 Winter Meeting
November 17-21, 2002
Washington, D.C., USA

Los Alamos
NATIONAL LABORATORY

Fluence-to-Dose Confusion Regarding External Stochastic Dose Determination within the DOE Complex

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Introduction

The Department of Energy's (DOE) occupational radiation protection dose limits are specified in 10 CFR 835 (hereafter referred to as "regulation") [1]. Ambiguity in the regulation regarding designation of dose and fluence-to-dose conversion factors leads to confusion and disagreement regarding the appropriate choice of conversion factors.

Three primary dose quantities of relevance are absorbed dose, D, quality factor, Q, and the product of those, called dose equivalent, H. The modifier Q is intended to express the long-term fatal cancer causing potential of different radiation types and generally increases with energy for neutrons. For photons, Q is close to unity regardless of energy.

In principle, H could be estimated by incorporating a phantom and relevant Q values in a radiation-transport model. In practice, this would entail too much model complexity and computer time. The evaluator of H instead relies on pre-calculated energy-dependent fluence-to-dose conversion factors.

Three primary sets of fluence-to-dose conversion factors are commonly used to determine stochastic dose for neutrons and photons: (1) ANSI/ANS-6.1.1-1977 [2] that incorporates the NCRP-38 [3] data for neutrons and sets based on Claiborne [4] and Wells [5] for photons, (2) ANSI/ANS-6.1.1-1991 [6] that are based on and nearly identical to the neutron and photon sets in ICRP-51 [7], and (3) neutron and photon sets in ICRP-74. The first set is maximum H values in a 30-cm diameter cylinder phantom for neutrons and in a 30-cm thick slab phantom for photons. The second set is effective dose equivalent, H_E, derived from an anthropomorphic phantom by summing the products of tissue dose equivalents, H_T, and tissue weighting factors, w_T. The third set is effective dose, E, also derived from an anthropomorphic phantom by summing the products of H_T and w_T. E is functionally identical to H_E except H_T is the product of D and the radiation weighting factor, w_R, which is similar in meaning to Q.

Problem

The regulation specifies the stochastic dose quantity to be H_E, but does not explicitly state which conversion factor sets should be used to determine H_E. Subtle verbiage in the regulation, along with the existence of other sets, instills confusion when choosing a set to compute H_E from neutron fluence. There is no mention in the regulation of a set to use for photons. The neutron conversion factors listed in the regulation are based on NCRP 38 and hence result in H instead of H_E. Many think that it would be more appropriate to use the H_E factors from ICRP 51. But the regulation merely suggests these factors "may be used", which implies that DOE still prefers the older NCRP 38 conversion factors that yield H, not H_E. Further confusion has resulted from informal communication from DOE [8] stating, "Thus, for design purposes any 'reputable' dose to fluence conversion would be acceptable." Does this statement imply that DOE thinks it is acceptable to use the ICRP-74 E conversion factors, which are widely accepted internationally?

Both the NCRP-38 and ICRP-51 neutron conversion factors incorporated Q values as a function of linear energy transfer (LET) of the secondary charged particles. A single Q value is listed for each conversion factor in NCRP-38; it is the maximum Q in a 30-cm single-region cylindrical phantom for the given incident neutron energy. Multiple unlisted Q values were calculated for each conversion factor in ICRP-51; each value is the maximum Q in a given organ inside an anthropomorphic phantom for the given incident neutron energy. Thus, the NCRP-38 Q values – one Q for one incident neutron energy - are conceptually inconsistent with the definition of H_E.

The differences between stochastic doses calculated with the different sets of conversion factors are within the error associated with generation of the factors and framework of shielding design and dose measurements. However, the ambiguity over which set is appropriate or legal causes confusion and expenditure of considerable time and discussion to resolve disagreements over which set to use. At Los Alamos, for example, most dose instrumentation calibrators use the NCRP-38 set, and most shielding design calculators use the ICRP-51 set. The calibrators suggest calculators should use the NCRP-38 set because they are incorporated in the regulation and in dose measurements and are thus “truth”. On the other hand, the calculators say the ICRP-51 set directly represents H_E, i.e. the average risk to the human body as incorporated in the w_T values.

Conclusions

It is recommended that the NCRP-38 neutron conversion factors and Q values be eliminated from the regulation as long as effective dose equivalent remains a specified stochastic dose. A better overall improvement would be to rewrite the regulation to explicitly allow use of newer conversions factors from standards organizations, i.e. NCRP, ICRP, and ANSI. An even better improvement would be endorsement of the latest internationally employed concept of effective dose.

Recognizing these concepts simply provide guidance in approximating possible stochastic effects of neutron radiation exposure, resultant differences in calculated dose quantities are often trivial. In any case, clarification of the inconsistent terminology is warranted and comments are welcomed from others within the complex performing H_E calculations.

References

1. Title 10 Part 835 “Occupational Radiation Protection” United States Code of Federal Regulations (1998).

2. “Neutron and Gamma-Ray Flux-to-Dose-Rate Factors,” American Nuclear Society, ANSI Standard ANSI/ANS-6.1.1-1977 (1977).

3. “Protection Against Neutron Radiation,” NCRP-38, National Council on Radiation Protection and Measurements, Washington, D.C. (1971).

4. CLAIBORNE, H.C., and D.K. TRUBEY, “Dose Rates in a Slab Phantom from Monoenergetic Gamma Rays,” Nuclear Applied Technology, 8, 450 (1970).

5. WELLS, M.B., and R.B. LIVESAY, “Calculations of Tissue Kerma Factors for Monoenergetic X-rays between 0.1 keV and 1.0 MeV,” Radiation Research Associates, Inc., Research Note RRA-N7216 (August 1, 1972).

6. “Neutron and Gamma-Ray Fluence-to-Dose Factors,” American Nuclear Society, ANSI Standard ANSI/ANS-6.1.1-1991 (1991).

7. “Data for Use in Protection Against External Radiation,” ICRP Publication 51, Pergamon Press, Oxford, U.K. (1987).

8. Personal electronic communication with J. Rabovsky, Department of Energy (December 29, 1999).